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Impact of climate change on agricultural production inputs and food security in Vietnam

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Abstract **Original Research Article**

This study employs several traditional analytical methods to examine the relationship between climate change (CC) and agricultural production, highlighting its negative impacts on Vietnam's food system. The results show that climate change is profoundly affecting Vietnam's agriculture through the depletion of water and soil resources, declining crop yields, and reduced aquatic resources. Irregular rainfall and river flow, together with upstream water exploitation, have intensified drought, salinization, and land degradation. Sea level rise poses a serious threat to the Mekong Delta, where up to 40% of the area could be inundated, significantly reducing agricultural productivity. Rising temperatures and extreme weather events have triggered pest outbreaks, decreasing rice yields by up to 10% per 1°C increase. Climate change also increases natural disasters, forest fires, biodiversity loss and causes great damage to farmers' livelihoods. This impact seriously threatens national food security, requiring Vietnam to apply many synchronous solutions (strengthening cooperation, sustainable management of resources, sustainable adaptation, etc.).

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1. INTRODUCTION

Vietnam's economy is heavily dependent on agricultural production and is among the five countries most severely affected by climate change (CC) [1]. The impacts of CC extend across multiple sectors — including natural resources, energy, food security, livelihoods, poverty, and development policies — posing significant challenges to national sustainability [2], [3]. Among all sectors, agriculture is the most vulnerable due to its direct exposure to extreme climate events such as landslides, flash floods, droughts, storms, heavy rainfall, cold spells, and frost, along with irregular weather patterns, pest outbreaks, sea-level rise, and saltwater intrusion [4]. Mountainous provinces and coastal regions are the most affected areas, where CC not only threatens livelihoods and food security but also exerts broad impacts on local socio-economic development and environmental stability. According to the Global Climate Risk Index by German watch, Vietnam ranks 6th among the world's top ten countries most vulnerable to climate risks [5]. The impacts of CC in Vietnam are evident across multiple dimensions. A 1-meter rise in sea level could result in the loss of approximately 5% of national land area—mostly agricultural land—reduce agricultural output by 7%, affect 11% of the population, and cause an estimated 10% GDP decline [6]. CC also leads to increased average temperatures, erratic rainfall, rising sea levels, and higher frequency and intensity of natural disasters such as droughts, heatwaves, floods, and tropical storms [7]. Furthermore, secondary and synergistic impacts may occur as CC interacts with socio-economic and political factors, exacerbating overall consequences.

Over the past six decades (1958–2018), Vietnam's climate has exhibited complex changes. Both average temperature and precipitation have increased, with more frequent extreme heat days nationwide. Although cold days have decreased, severe cold spells and rare snow or frost events have been recorded in northern mountainous provinces (notably in 2008, 2015, and 2016) [8]. Heavy rainfall events have become more frequent and intense, with increasingly unpredictable patterns. These changes have altered cultivation conditions and cropping calendars, increased the incidence of pests and diseases, and created additional challenges, causing severe losses to agriculture and threatening the long-term sustainability of the production system.

Therefore, the study aims to analyze the relationship between climate change and agricultural production, pointing out the negative impacts on the national food system, especially in key areas such as the Mekong Delta and the Red River Delta. The research results are an important basis for proposing appropriate solutions to enhance adaptation, minimize

impacts and risks of natural disasters caused by climate change, contributing to the sustainable development of the agricultural sector and ensuring food security in Vietnam.

2. RESEARCH METHODS

To conduct this study, the author applied a combination of research methods, including secondary research, comparative analysis, and data analysis and synthesis.

2.1. Data collection and synthesis method

The study collected available data, figures and documents from reliable domestic and international sources.

- Collected meteorological and statistical reports from the Ministry of Natural Resources and Environment (MONRE), the General Department of Meteorology and Hydrology, IPCC, UNDP, World Bank (WB), and FAO, among others.
- Compiled data on temperature, rainfall, storms, sea level rise, and socio-economic damages.
- Reviewed relevant research studies, scientific articles, and national reports on climate change.

2.2. Comparative method

- Compared climate change indicators among regions (North–Central–South) or between different time periods (e.g., before 1980 vs. after 2000).
- Compared Vietnam's data with that of Southeast Asia or global averages to determine the relative severity of climate change impacts.

2.3. Data analysis and processing method

- Utilized meteorological datasets on temperature, precipitation, storms, and sea level rise from the past 30–60 years.
- Employed statistical software such as Excel, SPSS, R, or Python to calculate trends, averages, standard deviations, and correlations.

3. RESULTS AND DISCUSSION

3.1. Impacts of climate change on agricultural production inputs

a) Impacts on water resources

Water is an essential resource for agricultural production, serving as a fundamental factor for the growth of crops and livestock, as well as for soil formation. Vietnam has more than 2,360 rivers over 10 km in length, including 109 major rivers. The average annual surface runoff of all river basins ranges from 830 to 840 billion m^3 per year. Due to its tropical monsoon climate, Vietnam has a relatively high average annual rainfall of about 1,940 mm [9]. In theory, this represents an abundant water resource that can adequately support agriculture and socio-economic activities. However, in practice, Vietnam remains among the countries facing water scarcity for three main reasons.

First, most of Vietnam's major river basins are transboundary, with approximately 72% of their catchment area lying outside the national territory. Exogenous water accounts for about 63% of total runoff (520–525 billion m^3), while endogenous water makes up only 37% (310–315 billion m^3) [10].

Second, water resources are unevenly distributed across regions and seasons. About 60% of total water is concentrated in the Mekong River Basin, 16% in the Red–Thai Binh River Basin, 4% in the Dong Nai River Basin, and 20% in other basins [9]. Rainfall occurs mainly during the three-month rainy season, while water in the dry season accounts for only 20–30% of the annual total, leading to prolonged droughts or severe floods when not properly managed [10].

Third, water quality is deteriorating due to increasing pollution [11]. Under the influence of climate change, rainfall quantity and distribution have become increasingly irregular, causing severe floods during the rainy season and prolonged droughts in the dry season [10]. In addition, upstream water extraction activities in countries such as China, Laos, and Cambodia have significantly reduced river flows into downstream Vietnam. With 63% of its surface water originating from outside its borders, reservoir and hydropower development in upstream countries could place Vietnam in a critical water shortage situation [9]. As a result, crop productivity declines, soil degradation worsens, saltwater intrusion intensifies, and sediment deposition decreases, leading to the loss of agricultural land [7]. Therefore, Vietnam must strengthen international cooperation—particularly with upstream nations—to establish a fair and sustainable mechanism for managing and allocating water resources in transboundary river basins such as the Mekong and Red–Thai Binh.

b) Impacts on soil resources

As of 2018, Vietnam's agricultural land area reached 26.44 million hectares, accounting for 79.82% of the country's total land area. However, land degradation has become increasingly widespread. In 2016, degraded land covered approximately 1.31 million hectares (4%), potentially degraded land 2.40 million hectares (7.3%), and land at risk of degradation 6.70 million hectares (20%)—a total of over 10 million hectares, or about 31% of the national territory. Climate change is one of the major drivers of soil degradation [12]. Rising temperatures and water shortages accelerate aridification and desertification, while floods and waterlogging wash away soil nutrients, reducing fertility [13, 14]. Vietnam is among the countries most affected by sea level rise, particularly in the Mekong Delta—one of the three most vulnerable deltas in the world [6, 15]. A one-meter rise in sea level could inundate about 40% of the Mekong Delta, 11% of the Red River Delta, and 3% of other coastal areas, rendering nearly 50% of the Mekong Delta's agricultural land uncultivable [12]. Sea level rise, coupled with reduced freshwater availability, exacerbates salinization, especially in the low-lying Mekong and Red River Deltas. Saltwater intrusion decreases the land-use coefficient from 3–4 crops per year to only 1–1.5 [15]. During the 2020 dry season, salinity intrusion in the Mekong Delta affected 340,000

hectares of rice, 136,000 hectares of fruit crops, and over 57% of agricultural land in Central Vietnam [16].

c) Impacts on crop productivity

Climate change alters ecological factors such as temperature, rainfall, and humidity, thereby affecting crop growth and pest dynamics [17]. The proliferation of pest species adapted to hot and humid climates—such as brown planthoppers and rice grassy stunt and ragged stunt viruses in the Mekong Delta—has caused serious agricultural losses [15]. Climate change influences crop yields through changes in cropping calendars, seasonal structure, farming techniques, and the quality of soil and water resources. Rising temperatures also reduce biodiversity and increase the risk of extinction among valuable crop varieties [7, 19]. In Vietnam, a 1°C rise in temperature may result in a 10% decline in rice yield, posing a severe threat to national food security. Studies by the Institute of Agricultural Environment indicate that by 2050, spring rice yields may decrease by 0.72 tons/ha, while maize yields may drop by 0.78 tons/ha [12, 20].

d) Impacts on fisheries

The fisheries sector depends directly on water availability and aquatic biodiversity. Vietnam currently has about 480,000 fishers, over 100,000 workers in seafood processing, and approximately 2.1 million people engaged in fisheries-related services (GSO, 2018). Extreme weather events such as heatwaves, storms, and floods have repeatedly caused mass fish deaths in rivers and coastal areas, resulting in substantial economic losses [20].

e) Impacts on forestry

Climate change exerts profound impacts on forestry, reflected in biodiversity loss, increased forest fires due to prolonged heat, mangrove degradation caused by sea level rise, and reduced biological productivity [12]. In particular, mangrove forests in the Mekong Delta have been shrinking due to rising sea levels, affecting melaleuca ecosystems and acid sulfate soil forests [15]. Rising temperatures and increased evaporation also hinder forest vegetation growth [17].

f) Climate change and increased natural disaster risks

According to the General Department of Disaster Prevention and Control, Vietnam frequently suffers from severe damage caused by storms, floods, droughts, and saltwater intrusion. Although there is no conclusive evidence that climate change directly causes natural disasters, most studies indicate that it increases their frequency and intensity [21]. Natural disasters and climate change have caused significant damage to agriculture, forestry, and fisheries. In the short term, floods and landslides reduce agricultural and aquaculture productivity; in the medium term, salinity intrusion degrades water quality; and in the long term, permanent inundation, prolonged droughts, and ecosystem shifts lead to farmland loss and crop failure [19].

3.2. Climate change threatens national food security

Climate change is closely linked to the food production system, in which agriculture is both a cause and a victim of its impacts. Globally, food production accounts for about one-third of total greenhouse gas (GHG) emissions, including 39% from fertilizer production and use processes and 35% from methane emissions in livestock and crop cultivation [22]. In Vietnam, agriculture contributes 35.8% of total GHG emissions, with rice cultivation accounting for 50%, livestock 19%, and fertilizer use and land management 13% [23].

As one of the world's leading food exporters, Vietnam faces increasing risks to food security as climate change directly affects the natural factors underpinning its agricultural system. Rice cultivation—occupying 94% of the country's arable land—is concentrated mainly in the Mekong Delta (54.47%) and the Red River Delta (24.08%), the two regions most severely affected by climate change, particularly by saltwater intrusion and sea level rise [18].

Fluctuations in temperature and rainfall intensify extreme weather phenomena such as heatwaves, droughts, heavy rainfall, floods, and soil erosion, causing significant damage to rice and other key crops [24]. Under projected climate change scenarios, Vietnam could lose approximately 40,000 km² of land (equivalent to 12.1% of its total area), affecting 17.1 million people, or 23.1% of the population [25]. In the Mekong Delta, sea level rise and declining freshwater availability may lead to 1.3–1.7 million hectares of farmland becoming saline, posing a serious threat to national food security if timely adaptive measures are not implemented.

4. CONCLUSION

Climate change is exerting profound impacts on the key inputs of Vietnam's agricultural production, depleting natural resources, reducing productivity, and threatening national food security. Water resources—the core element of agricultural production—are under significant stress due to irregular changes in rainfall quantity and distribution, compounded by excessive water exploitation in upstream countries. Approximately 63% of Vietnam's surface water originates from outside its borders, so dam and reservoir construction on the Mekong and Red–Thai Binh River basins has reduced downstream flow, leading to water shortages, salinity intrusion, sediment loss, and declining crop yields. Soil resources are also severely degraded. Over 10 million hectares (about 31% of Vietnam's natural land area) are experiencing various levels of degradation. Rising temperatures, droughts, erratic floods, and sea level rise accelerate nutrient leaching, reduce soil fertility, and promote desertification. In the Mekong Delta, a 1-meter rise in sea level could inundate 40% of the region's area, eliminating nearly half of its cultivable land. Saltwater intrusion reduces the land-use intensity from 3–4 crops per year to only 1–1.5 crops, severely affecting productivity and livelihoods. Climate change also disrupts crop growth and increases pest infestations, particularly tropical pests such as brown

planthopper, grassy stunt, and ragged stunt diseases. A 1°C temperature increase could reduce rice yields by about 10%, posing a grave threat to food security. By 2050, spring rice yields are projected to decline by 0.72 tons/ha, and maize by 0.78 tons/ha. In the fisheries sector, extreme weather events such as heatwaves, storms, and floods have caused mass mortality of aquatic species, reducing stock abundance and the incomes of hundreds of thousands of coastal workers. The forestry sector is also affected through declining biodiversity, increased forest fires, shrinking mangrove areas, and reduced biological productivity. Furthermore, climate change amplifies the risks of natural disasters, with increasing frequency and intensity. Droughts, salinity intrusion, storms, and landslides cause severe losses to agriculture, forestry, and fisheries, directly affecting millions of rural livelihoods. In the long term, agricultural land may be permanently lost due to inundation and ecosystem shifts. Climate change not only affects production but also poses a direct threat to national food security. Vietnam's agriculture—responsible for roughly 35.8% of total GHG emissions—is both a contributor to and victim of climate change. The two major rice-growing regions, the Mekong and Red River Deltas, are most vulnerable to saltwater intrusion and sea level rise. Under future scenarios, Vietnam could lose around 40,000 km² of land (12.1% of its territory), affecting more than 17 million people. Of this, about 1.3–1.7 million hectares of farmland in the Mekong Delta are at risk of salinization, posing a critical challenge to national food security unless timely adaptation measures are taken.

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